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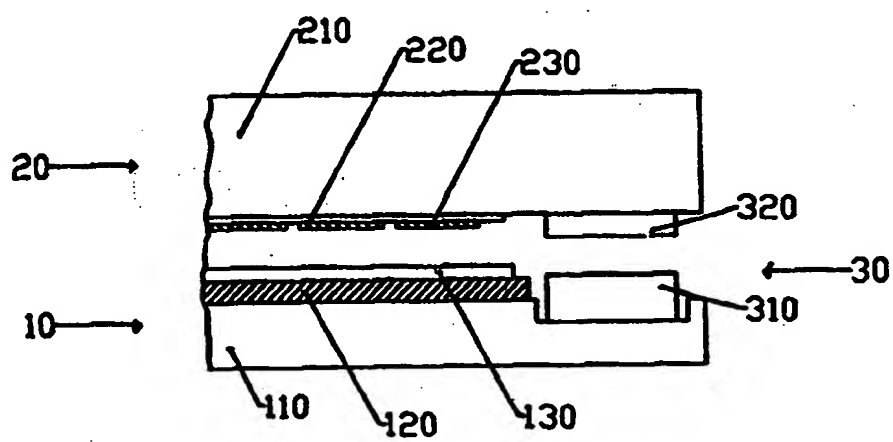
(54) Title: BONDED ACTIVE MATRIX ORGANIC LIGHT EMITTING DEVICE DISPLAY AND METHOD OF PRODUCING THE SAME



(57) Abstract

The present invention is directed to a method of forming an active matrix organic light emitting device display. The method includes the steps of providing an organic light emitting plate assembly, providing an active matrix assembly, and sealing the organic light emitting plate assembly to the active matrix assembly. The active matrix plate assembly may include a substrate, drive circuitry formed thereon, and at least one pixel pad. The at least one pixel pad may be formed from an electron injector material. The electron injector material may be selected from one of the group consisting of Mg+Al, Al+Li, LiF/Al and CsC. The method may further include the step of cleaning the at least one pixel pad prior to the step of sealing the organic light emitting plate assembly to the active matrix plate assembly. The cleaning step may include the step of ion beam cleaning of at least one pixel pad.

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BONDED ACTIVE MATRIX ORGANIC LIGHT EMITTING DEVICE DISPLAY AND METHOD OF PRODUCING THE SAME

Cross Reference To Related Patent Application

This application relates to and claims priority on provisional application serial number 60/052,357, filed July 11, 1997 and entitled "Bonded Active Matrix Organic Light Emitting Display."

Field of the Invention

The present invention relates to organic light emitting devices. In particular, the present invention relates to a method of sealing an organic light emitting device plate and an active matrix plate sealed together to create a high performance video display.

Background of the Invention

Light emitting devices, which may be generally classified as organic or inorganic, are well known in the graphic display and imaging art. Among the benefits of organic light emitting devices are high visibility due to self-emission, as well as high power efficiency, and ease of handling of the solid state devices. Organic light emitting display devices may have practical application for television and graphic displays, as well as in digital printing applications.

An organic light emitting display device is typically a laminate formed on a substrate such as soda-lime glass. A light-emitting layer of a luminescent organic solid, as well as adjacent semiconductor layers, are sandwiched between a cathode and an anode. The semiconductor layers may be hole-injecting and electron-injecting layers. The light-emitting layer may be selected from any of a multitude of light emitting organic solids. The light-emitting layer may consist of multiple sublayers.

When a potential difference is applied across the cathode and anode, electrons from the electron-injecting layer, and holes from the hole-injecting layer are injected into the light-emitting layer. They recombine, emitting light.

In a typical matrix-addressed organic light emitting display device, numerous light emitting devices are formed on a single substrate and arranged in groups in a regular grid pattern. Several light emitting device groups forming a column of the grid may share a common cathode, or cathode line. Several light emitting device groups forming a row of the grid may share a common anode, or anode line. The individual light emitting devices in a given group emit light when their cathode and anode are activated at the same time. Activation may be by rows and columns or in an active matrix with individual cathode or anode pads.

Organic light emitting devices have a number of beneficial characteristics. These include a low activation voltage (about 3 to 6 volts), fast response when formed with a thin light-emitting layer, and high brightness in proportion to the injected electric current. By changing the kinds of organic solids making up the light-emitting layer, many different colors of light may be emitted, ranging from visible blue, to green, yellow, and red. Organic light emitting devices are currently the subject of aggressive investigative efforts.

Organic light emitting devices need to be protected from the atmosphere. The light emitting organic material in the light-emitting layer can be highly reactive. The material is susceptible to water, oxygen, etc. Moisture and oxygen may cause a reduction in the useful life of the light emitting device. The cathode and anode may also be affected by oxidation. One disadvantage of oxygen and moisture penetration into the interior of the organic light emitting device is the potential to form metal oxides at the metal-organic interface. These metal oxide impurities may allow separation of the cathode or anode and the organic in a matrix addressed OLED, especially the oxidation sensitive cathode, such as, Mg-Ag or Al-Li. This can result in the formation of dark non-emitting spots (i.e., no illumination) because no current flows through the area of the separation.

As discussed above, exposing a conventional light emitting device to the atmosphere shortens its life. To obtain a practical, useable organic light emitting device, it is necessary to protect the device, so that water, oxygen, etc., do not infiltrate the light-emitting layer.

Methods commonly employed for protecting or sealing inorganic light emitting devices are typically not effective for sealing organic light emitting devices. Resin

coatings that have been used to protect inorganic light emitting devices are not suited for organic light emitting devices. The moisture and oxygen permeability of even the best organic adhesives is far too high, and the organic light emitting device often degrades due to chemical or mechanical effects.

The present invention is directed to a method for processing active matrix organic light emitting device displays with nontransparent substrates, such as, for example, silicon. Non-transparent substrates provide a low cost method for obtaining active matrix circuitry and high performance drivers, along with an opportunity to integrate other system or display functions into small-medium size displays. The organic light emitting device can be fabricated using this method without the need for silicon substrate planarization, and with optimized organic light emitting device structures on an independent glass plate.

Objects of the Invention

It is therefore an object of the present invention to bond an OLED plate and an active matrix plate together to create a high performance video display.

It is another object of the present invention to provide a method for processing active matrix OLED displays with non-transparent substrates such as silicon.

It is a further object of the present invention to provide a low cost method for obtaining active matrix circuitry and high performance drivers, along with an opportunity to integrate other system or display functions into small to medium sized displays.

It is still another object of the present invention to provide a method for fabricating an active matrix OLED without the need for silicon substrate planarization, and with optimized OLED structures on an independent glass plate.

It is still yet another object of the present invention to provide a method of sealing the active matrix substrate and the OLED plate together to bring the two plates into intimate contact.

Additional objects and advantages of the invention are set forth, in part, in the description which follows and, in part, will be apparent to one of ordinary skill in the art from the description and/or from the practice of the invention.

Summary of the Invention

The present invention is directed to a method of forming an active matrix organic light emitting device display. The method includes the steps of providing an organic light emitting plate assembly, providing an active matrix plate assembly, and sealing the organic light emitting plate assembly to the active matrix assembly.

The active matrix plate assembly may include a substrate, drive circuitry formed thereon, and at least one pixel pad. The at least one pixel pad may be formed from an electron injector material. The electron injector material may be selected from one of the group consisting of Mg+Al, Al+Li, LiF/Al and CsC.

The method may further include the step of cleaning the at least one pixel pad prior to the step of sealing the organic light emitting plate assembly to the active matrix plate assembly. The cleaning step may include the step of ion beam cleaning of at least one pixel pad.

The organic light emitting plate assembly may include a substrate, a conductor layer and at least one OLED layer. The organic light emitting plate assembly may further include at least one color filter.

The step of sealing the organic light emitting plate assembly to the active matrix plate assembly may comprise the steps of locating the organic light emitting plate assembly and the active matrix plate assembly in a sealing environment, and securing a perimeter of the organic light emitting plate assembly to a perimeter of the active matrix plate assembly. The environment may be one of a vacuum environment, an inert gas environment and a moisture absorbing gas environment.

The step of securing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly may include sealing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly with a fused metal seal. Alternatively, the step of securing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly may include sealing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly with a polymer. The polymer may be a low moisture diffusivity polymer. The low moisture diffusivity polymer may be a two-component adhesive, or cured by heat or ultraviolet light.

The sealing of the organic light emitting plate assembly to the active matrix plate assembly may be done in a low-pressure inert environment by bringing the surfaces of the two assemblies into intimate contact, and may include the application of pressure and/or heat.

The present invention is also directed to a high performance display including an organic light emitting device, an active matrix substrate; and an assembly for bonding the organic light emitting device to the active matrix substrate. The organic light emitting device may include a substrate, at least one conductor formed on the substrate, and a first insulator layer formed on the conductor. The organic light emitting device may include a color filter disposed between the substrate and the conductor. The organic light emitting device may include a color conversion filter disposed between the substrate and the conductor.

The substrate may be a thin transparent material. The active matrix substrate may include a second substrate, independently addressed pixel pads, and driver circuitry. The active matrix substrate may be fabricated on a non-transparent substrate.

The independently addressed pixel pads may be produced from an electron injector material with high vertical conductivity and low horizontal conductivity. The independently addressed pixel pads make contact with the organic light emitting device. The independently addressed pixel pads may be elevated by at least one insulator. The independently addressed pixel pads may be elevated by stacking the pixel pads on top of at least one lower silicon circuit structure.

The organic light emitting device and the active matrix substrate may be sealed together in an inert or moisture-reactive gas environment. The organic light emitting device and the active matrix substrate may be sealed together using a fused metal seal.

The organic light emitting device and the active matrix substrate may be sealed together using at least one low moisture diffusivity polymer. The low moisture diffusivity polymer may be a non-solvent containing epoxy or acrylic. The low moisture diffusivity polymer may be a UV or heat cured adhesive.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed. The accompanying drawings, which are incorporated herein by reference, and which constitute a part of this specification, illustrate certain

embodiments of the invention, and together with the detailed description serve to explain the principles of the present invention.

Brief Description of the Drawings

Fig. 1 is a side view of an active matrix organic light emitting display device prior to assembly according to the present invention;

Fig. 2 is a side view of the active matrix organic light emitting display device in an assembled state according to the present invention; and

Fig. 3 is a side view of an active matrix organic display device prior to assembly with OLED stacks on both assemblies according to the present invention.

Detailed Description of the Preferred Embodiments

Reference will now be made in detail to a preferred embodiment of the present invention, an example of which is illustrated in the accompanying drawings. The present invention is directed to an improved light emitting device **1** that includes an organic light emitting plate assembly **10** that is secured to an active matrix plate assembly **20**.

The organic light emitting plate assembly **10** includes a substrate **110**. The substrate **110** is preferably formed from a transparent material such as, for example, mylar or glass. It, however, is contemplated by the inventors of the prevention that other suitable materials may be used for forming the substrate **110**. This substrate might be particularly flat and flexible. A conducting layer **120** is formed on the substrate **110**. The conducting layer **120** is preferably formed from indium tin oxide (ITO). A planar OLED stack **130** is formed on the conducting layer **120**. The OLED stack **130** may include an electron injector material with high vertical conductivity and low horizontal conductivity. The electron injector material may be LiF.

The organic light emitting plate assembly **10** may include at least one color changing filter **140**. The at least one color changing filter **140** is probably located between the substrate **110** and the conducting layer **120**. The surfaces of the OLED materials and the filters should be smooth and nearly planar to ensure proper orientation with the plate assembly **20** after fabrication. Alternatively, the OLED materials may be patterned into red, green and blue emitters to produce a color display. A color display

may also be produced by patterning part of the color OLED emitter on one substrate and the other two color OLED emitters on another substrate, as shown in Fig.3. This makes direct shadow masking of direct color organic light emitting display devices more simple.

The active matrix plate assembly **20** includes a substrate **210**. The substrate **210** is preferably formed from silicon or another suitable substrate material. The active matrix plate assembly **20** further includes driver circuitry and other system related electronics **220**. The matrix plate assembly **20** preferably includes CMOS drivers and transistor and capacitor cells.

The active matrix plate assembly **20** also includes at least one pixel pad **230**. Each pixel pad **230** corresponds to a pixel on the display device and is independently addressable. Each pixel pad **230** is preferably formed from a good quality electron injector material. The electron injector material may be formed from Mg+Ag, Al+Li, LiF/Al or CSC. The present invention is not limited to these materials or polarlity; rather, it is contemplated that other suitable injector materials may be used. Each pixel pad **230** must be sized such that it contacts the OLED stack **130** when the organic light emitting plate assembly **10** is secured to the active matrix plate assembly **20**. A thickness of between 0.5-10 microns is acceptable for this purpose. The pixel pads **230** may be elevated by other structures, such as, for example, a thick insulator and a via plug. Additionally, the pixel pads **230** may be stacked on top of lower silicon circuit structures. Additionally, a shallow trench might be etched for the seal.

A sealing assembly **30** is provided to secure the organic light emitting plate assembly **10** to the active matrix plate assembly **20**. The sealing assembly **30** preferably includes a first sealing assembly **310** formed on the organic light emitting plate assembly **10** and a second sealing assembly **320** formed on the active matrix plate assembly **20**. The sealing assembly **30** may be a fused metal seal. The sealing assembly **30** is not limited to a metal seal; rather, low moisture diffusing polymers including but not limited to a non-solvent containing a UV or heat cured adhesive may be used.

The method of sealing the organic light emitting plate assembly **10** to the active matrix plate assembly **20** will now be described.

The active matrix plate assembly **20** is formed by fabricating the driver circuitry and other system related electronics **220** on the substrate **210**. The active matrix plate assembly **20** may be fabricated using known techniques. The organic light emitting plate

assembly **10** is formed by fabricating an OLED structure on a substrate **110**. The OLED structure may be formed using known techniques. The OLED structure includes the conducting layer **120**, the planar OLED stack **130**. The OLED structure may further include at least one color changing filter **140**.

A first sealing assembly **310** is formed along the perimeter of the organic light emitting plate assembly **10**. A second sealing assembly **320** is formed along the perimeter of the active matrix plate assembly **20**. The plate assemblies **10** to **20** are located in a vacuum or inert gas environment. The first and second sealing assemblies **310** and **320** are then brought into contact. After sealing, the light emitting device **1** is removed from the low-pressure environment. Under the influence of atmospheric pressure, the plate assemblies **10** to **20** move into intimate contact such that each pixel pad **230** is in contact with the organic light emitting plate assembly **10**. This works when the pressure of the inert gas inside is sufficiently below the ambient pressure.

It is important to avoid air and moisture exposure between the preparation of the plate assemblies **10** to **20** and the sealing operation. Accordingly, the entire fabrication process may take place in a vacuum or an inert gas environment. Alternatively, a moisture reactive gas may be employed to keep the surfaces of the plate assemblies **10** to **20** free of moisture before and during the sealing process. Non-vacuum sealing can best be performed by applying pressure in the center of one or both of the plastic assemblies **10** to **20**. Alternatively, one or both of the plastic assemblies **10** to **20** may be bowed prior to sealing.

The pixel pads **230** may be ion bean cleaned prior to sealing the plastic assemblies **10** to **20** together.

While the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art. For example, the above-described method may be used with other TFT active matrix substrates when larger displays are fabricated. This permits more processing options and the ability to build transport displays. The above-described method can also be used for passive OLED fabrication where the election injector/conductor lines and ITO/OLED lines cross over at the OLED light generating pixels. Additionally, the OLED structure can be built on either the transparent conductor side or the active matrix side of the plate assembly **10**. If the OLED structure is reversed

with the hole injector on top, then a gold interface layer can be used on the pixel pads 230. Furthermore, a thin Mg+Ag, A1+Li, LiF/A1 or CsC layer can act as a transparent electron injector on the transport ITO layer. Accordingly, the preferred embodiments of the invention as set forth herein are intended to be illustrative, not limiting. Various changes may be made without departing from the spirit and scope of the invention as defined in the following claims.

What is Claimed Is:

1. A method of forming an active matrix organic light emitting device display, said method comprising the steps of:

providing an organic light emitting plate assembly;

providing an active matrix plate assembly; and

sealing the organic light emitting plate assembly to the active matrix assembly.

2. The method according to Claim 1, wherein the active matrix plate assembly includes a substrate, drive circuitry formed thereon, and at least one pixel pad.

3. The method according to Claim 2, wherein the at least one pixel pad is formed from an electron injector material.

4. The method according to Claim 3, further comprising the step of cleaning the at least one pixel pad prior to the step of sealing the organic light emitting plate assembly to the active matrix plate assembly.

5. The method according to Claim 4, wherein said cleaning step includes step of ion beam cleaning of the at least one pixel pad.

6. The method according to Claim 3, wherein the electron injector material is selected from one of the group consisting of Mg+Al, Al+Li, LiF/Al and CsC.

7. The method according to Claim 1, wherein the organic light emitting plate assembly includes a substrate, a conductor layer and at least one OLED layer.

8. The method according to Claim 7, wherein the organic light emitting plate assembly further includes at least one color filter.

9. The method according to Claim 1, wherein said step of sealing the organic light emitting plate assembly to the active matrix plate assembly comprises the steps of:

locating the organic light emitting plate assembly and the active matrix plate assembly in a sealing environment; and

securing a perimeter of the organic light emitting plate assembly to a perimeter of the active matrix plate assembly.

10. The method according to Claim 9, wherein the environment is one of a vacuum environment, an inert gas environment and a moisture absorbing gas environment.

11. The method according to Claim 9, wherein said step of securing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly includes sealing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly with a fused metal seal.

12. The method according to Claim 9, wherein said step of securing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly includes sealing the perimeter of the organic light emitting plate assembly to the perimeter of the active matrix plate assembly with a polymer.

13. The method according to Claim 12, wherein the polymer is a low moisture diffusivity polymer.

14. The method according to Claim 13, wherein the low moisture diffusivity polymer is at least one of a two-component adhesive, and cured by heat or ultraviolet light.

15. The method according to Claim 9, wherein the organic light emitting plate assembly includes a first surface and the active matrix plate assembly includes a second surface, said step of sealing the organic light emitting plate assembly to the active matrix plate assembly further comprises the steps of:

moving the organic light emitting plate assembly and active matrix plate assembly into a low-pressure environment; and

moving the first surface of the organic light emitting plate assembly into contact with the second surface of the active matrix plate assembly.

16. The method according to Claim 15, wherein said step of moving the first surface of the organic light emitting plate assembly into contact with the second surface of the active matrix plate assembly includes applying at least one atmospheric pressure and heat to the organic light emitting plate assembly and the active matrix plate assembly.

17. A high performance video display comprising:

an organic light emitting device;

an active matrix substrate; and

means for bonding said organic light emitting device to said active matrix substrate.

18. The high performance video display according to claim 17, wherein said organic light emitting device further comprises:

a substrate;

at least one conductor formed on said substrate; and

a first insulator layer formed on said conductor.

19. The high performance video display according to Claim 18, wherein said organic light emitting device comprises a color filter disposed between said substrate and said conductor.

20. A high performance video display according to claim 19, wherein said organic light emitting device comprises a color conversion filter disposed between said substrate and said conductor.

21. The high performance video display according to claim 18, wherein said substrate is a thin transparent material.

22. The high performance video display according to claim 21, wherein said substrate is flexible.

23. The high performance video display according to claim 17, wherein said active matrix substrate further comprises:

a second substrate;

independently addressed pixel pads; and

driver circuitry.

24. The high performance video display according to claim 23, wherein said active matrix substrate is fabricated on a non-transparent substrate.

25. The high performance video display according to claim 23, wherein said independently addressed pixel pads are produced from an electron injector material with high vertical conductivity and low horizontal conductivity.

26. The high performance video display according to claim 23, wherein said independently addressed pixel pads make contact with said organic light emitting device.

27. The high performance video display according to claim 23, wherein said independently addressed pixel pads are elevated by at least one insulator(s).

28. The high performance video display according to claim 23, wherein said independently addressed pixel pads are elevated by stacking said pixel pads on top of at least one lower silicon circuit structure.

29. The high performance video display according to Claim 17, wherein said organic light emitting device and said active matrix substrate are sealed together in an inert or moisture-reactive gas environment.

30. The high performance video display according to Claim 17, wherein said organic light emitting device and said active matrix substrate are sealed together using fused metal seals.

31. The high performance video display according to Claim 17, wherein said organic light emitting device and said active matrix substrate are sealed together using at least one low moisture diffusivity polymer.

32. The high performance video display according to claim 31, wherein said low moisture diffusivity polymer is a non-solvent containing one of epoxy and acrylic resin.

33. The high performance video display according to claim 31, wherein said low moisture diffusivity polymer is one of a heat cured adhesive and UV cured adhesive.

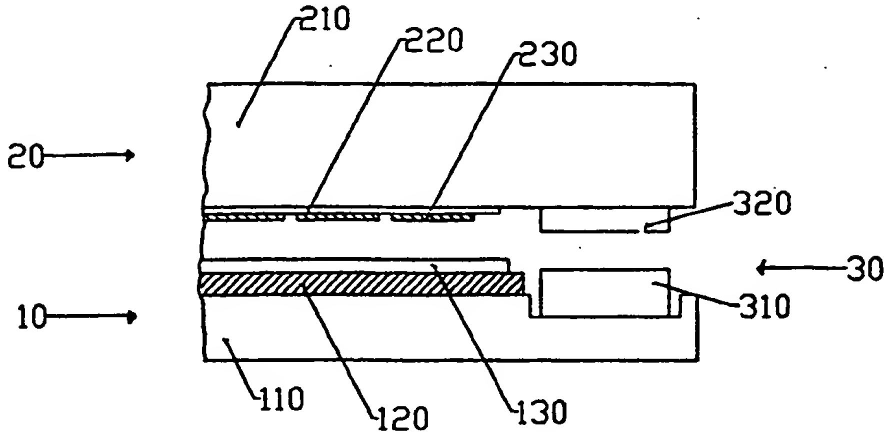

FIG. 1

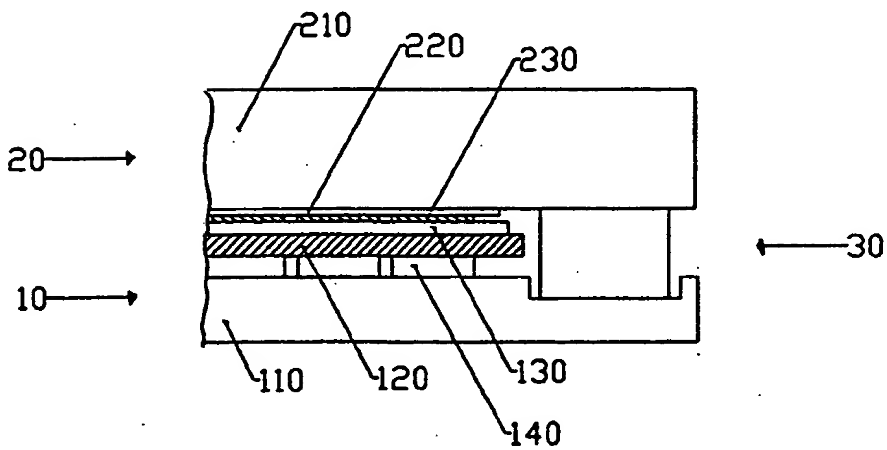

FIG. 2

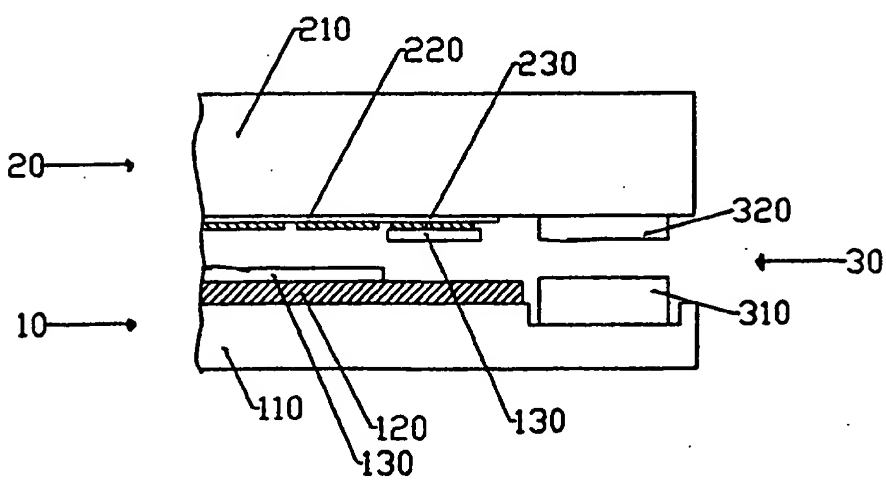

FIG. 3